AP® ENVIRONMENTAL SCIENCE
2014 SCORING GUIDELINES

Question 2

Fremont Water Data
The shopping center's parking lot is 200 meters long and 100 meters wide.
Fremont has an area of 10 km^2.
Impervious surfaces cover 20 percent of Fremont's area.
The FWTP typically treats 5,000 m^3 of domestic sewage per day.
The FWTP has the capacity to treat 10,000 m^3 of combined sewage and storm water per day.

(a) Identify TWO specific pollutants in storm-water runoff that degrade the quality of surface water.
(2 points: 1 point for each bulleted pollutant)

- Nitrogen/nitrates/NO_3^-
- Phosphorus/phosphates/PO_4^{3-}
- Fertilizers
- Pesticides/herbicides
- Silt/sediment/soil
- Pathogens (two specific pathogens can each earn 1 point):
  - *E. coli*/coliform bacteria
  - *Salmonella*
  - *Cryptosporidium*
- Ammonia/nitrogenous wastes
- Animal feces
- [Road] salts
- Motor oil
- Grease
- Antifreeze
- Rubber (tire residue)
- Gasoline
- Trash (e.g., plastics, garbage, cigarette butts)
- Detergents
- Sulfuric/nitric acid from acid rain
- Mercury from contaminated rainfall

Question 2 (continued)

(b) Calculate the volume of water (in m^3) that runs off the Shoppes at Fremont parking lot after a 5 cm rainfall event. Assume that all the water that falls on the parking lot runs off.
(2 points: 1 point for a correct setup and 1 point for the correct answer)

$[200\ m \times 100\ m = 20{,}000\ m^2 \text{ or } 2 \times 10^4\ m^2]$

$\left[5\ cm \times \frac{1\ m}{100\ cm} = 0.05\ m\right]$

$200\ m \times 100\ m \times 0.05\ m = 1{,}000\ m^3 \text{ or } 1 \times 10^3\ m^3$

(Note: Units are not required in the answer; however, students must show the calculation in order to receive credit for the correct answer.)

(c) Calculate the volume of storm-water runoff (in m^3) generated in all of Fremont by the 5 cm rainfall event. Assume that only the impervious surfaces generate runoff.
(2 points: 1 point for a correct setup and 1 point for the correct answer)

$\left[5\ cm \times \frac{1\ m}{100\ cm} = 0.05\ m\right]$

$\left[10\ km^2 \times \frac{1 \times 10^6\ m^2}{1\ km^2} = 10{,}000{,}000\ m^2 \text{ or } 1 \times 10^7\ m^2\right]$

$0.05\ m \times 1 \times 10^7 m^2 \times 0.20 = 100{,}000\ m^3 \text{ or } 1 \times 10^5\ m^3$

OR

$5\ cm \times \frac{1\ m}{100\ cm} \times 10\ km^2 \times \frac{1 \times 10^6\ m^2}{1\ km^2} \times 0.20 = 100{,}000\ m^3 \text{ or } 1 \times 10^5\ m^3$

(Note: Units are not required in the answer; however, students must show the calculation in order to receive credit for the correct answer.)

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2014 SCORING GUIDELINES

Question 2 (continued)

(d) Assume that all the runoff that you calculated in part (c) is captured by the storm sewers in one day. Calculate the volume of untreated water (in m^3) that bypasses the plant as a result of the storm. (Note that the plant still receives 5,000 m^3 of domestic sewage per day.)

(1 point for the correct answer, with work shown)

$$100{,}000\ m^3 + 5{,}000\ m^3 - 10{,}000\ m^3 = 95{,}000\ m^3$$

OR

$$[10{,}000\ m^3 - 5{,}000\ m^3 = 5{,}000\ m^3]$$

$$100{,}000\ m^3 - 5{,}000\ m^3 = 95{,}000\ m^3$$

(e) Describe TWO ways that the volume of storm-water runoff can be reduced.

(2 points: 1 point for each description of a strategy for reducing storm-water runoff)

- Decreasing area covered by impervious surfaces would increase infiltration of storm water
- Increasing area covered by trees/vegetation would increase infiltration/allow for greater uptake of storm water
- Creating basins/ponds to hold storm water
- Creating wetlands to absorb storm water
- Installing rain barrels, cisterns, or other devices to hold storm water
- Using green roofs or rooftop gardens to use rainwater
- Contour farming/terracing to allow water to infiltrate soil

(f) Describe one environmental problem (other than pollution from runoff and from untreated sewage) that results from having extensive paved areas.

(1 point can be earned for a description of an environmental problem)

- Habitat destruction/biodiversity loss caused by the removal of vegetation (or other plausible description of a mechanism for habitat destruction/biodiversity loss)
- Habitat fragmentation caused by roads dividing habitat into smaller areas
- Microclimate caused by paved surfaces absorbing heat/solar energy and releasing heat [at night]
- Flooding/bank erosion/turbidity/loss of aquatic organisms caused by excessive runoff into surface waters
- Groundwater depletion because water runs off rather than infiltrating soil/recharging aquifers
- Drying of soil/subsidence/formation of sinkholes because water runs off instead of infiltrating soil
- Erosion caused by flooding/excessive runoff
- Flooding caused by excessive runoff/lack of infiltration of storm water

2A1

2. Like many communities, Fremont has a combined sewer system that collects both sewage and storm water. When storm water runs into storm drains that connect to the city's sanitary sewer system, the storm water and sewage flow together to the Fremont Wastewater Treatment Plant (FWTP). During a major storm event, however, the combined volume of storm water and sewage may exceed the plant's capacity, and the overflow bypasses the FWTP. The untreated overflow is discharged into Fremont Creek along with the treated waste.

Recently parts of Fremont received 5 cm of rain in 60 minutes. The storm caused widespread flooding in the northeast section of town. Especially hard hit was the Shoppes at Fremont shopping center.

Use the data from the table below to answer the questions that follow. Show all calculations.

Fremont Water Data
The shopping center's parking lot is 200 meters long and 100 meters wide.
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The FWTP has the capacity to treat 10,000 m^3 of combined sewage and storm water per day.

(a) **Identify** TWO specific pollutants in storm-water runoff that degrade the quality of surface water.

(b) **Calculate** the volume of water (in m^3) that runs off the Shoppes at Fremont parking lot after a 5 cm rainfall event. Assume that all the water that falls on the parking lot runs off.

(c) **Calculate** the volume of storm-water runoff (in m^3) generated in all of Fremont by the 5 cm rainfall event. Assume that only the impervious surfaces generate runoff.

(d) Assume that all the runoff that you calculated in part (c) is captured by the storm sewers in one day. **Calculate** the volume of untreated water (in m^3) that bypasses the plant as a result of the storm. (Note that the plant still receives 5,000 m^3 of domestic sewage per day.)

(e) **Describe** TWO ways that the volume of storm-water runoff can be reduced.

(f) **Describe** one environmental problem (other than pollution from runoff and from untreated sewage) that results from having extensive paved areas.

a) In storm-water runoff, pollutants such as nitrates and phosphates can degrade the quality of surface water.

b) $(200\ m) \times (100\ m) \times (0.05\ m) = (200.00\ m^2)(0.05\ m)$

$= 1000\ m^3$ of water runs off the parking lot

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ADDITIONAL PAGE FOR ANSWERING QUESTION 2

c) $\frac{10 \text{ km}^2 \mid 1000^2 \text{ m}^2}{1 \text{ km}^2} = 10 \cdot 1000 \cdot 1000 \text{ m}^2$

$= 10{,}000{,}000 \text{ m}^2$

impervious surfaces $= 0.2 \times 10{,}000{,}000$

$= 2 \times 10^6 \text{ m}^2$

Volume of run-off $= (2 \times 10^6 \text{ m}^2)(5 \times 10^{-2} \text{ m})$

$= 10 \times 10^4 \text{ m}^3 = \boxed{1.0 \times 10^5 \text{ m}^3}$

run-off in all of Fremont.

d) $1.0 \times 10^5 \text{ m}^3 + 5 \times 10^3 \text{ m}^3 - 1.0 \times 10^4 \text{ m}^3$

$= 105000 - 10000 = \boxed{95{,}000 \text{ m}^3 \text{ untreated water}}$

e) The volume of storm water runoff can be reduced by reducing the area that impervious surfaces cover. This would allow some water to slowly percolate or infiltrate through the ground naturally. Run off can be further reduced by creating large basins to collect the gray water and use it. For example, cities could use gray water when flushing toilets, an activity that would not harm human health.

FLIP PAGE

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2A3

f) Extensively paved areas can reduce infiltration greatly. As a result, [redacted] groundwater that is being used is [redacted] being replenished at a greatly reduced rate; most likely, [redacted] the aquifer is not being replenished almost at all.

2. Like many communities, Fremont has a combined sewer system that collects both sewage and storm water. When storm water runs into storm drains that connect to the city's sanitary sewer system, the storm water and sewage flow together to the Fremont Wastewater Treatment Plant (FWTP). During a major storm event, however, the combined volume of storm water and sewage may exceed the plant's capacity, and the overflow bypasses the FWTP. The untreated overflow is discharged into Fremont Creek along with the treated waste.

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Use the data from the table below to answer the questions that follow. Show all calculations.

6m ha in 1 hr

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1000 $1x10^3 \times 2x10^3$ 2×10^6

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(b) **Calculate** the volume of water (in m^3) that runs off the Shoppes at Fremont parking lot after a 5 cm rainfall event. Assume that all the water that falls on the parking lot runs off.

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(d) Assume that all the runoff that you calculated in part (c) is captured by the storm sewers in one day. **Calculate** the volume of untreated water (in m^3) that bypasses the plant as a result of the storm. (Note that the plant still receives 5,000 m^3 of domestic sewage per day.)

(e) **Describe** TWO ways that the volume of storm-water runoff can be reduced.

(f) **Describe** one environmental problem (other than pollution from runoff and from untreated sewage) that results from having extensive paved areas.

2 a) Oils from vehicles on the roads and human litter and waste are pollutants in storm water runoff harmful to water quality.

b) 200 meters × 100 meters = 20,000 meters^2

$2 \times 10^4 m^2 \times .05$ m of rainfalls

$2 \times 10^4 \times 5 \times 10^{-2} = 10 \times 10^2 m^3$

1000 m^3 of rainwater runs off

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ADDITIONAL PAGE FOR ANSWERING QUESTION 2

c.) 20% of $10\ km^2$ = $2\ km^2$

$2\ km^2$ = $2 \times 10^6\ m^2$

$2 \times 10^6\ m^2 \times 5 \times 10^{-2}\ m = 10 \times 10^4\ m^3$

$= 100{,}000 = 1 \times 10^5\ m^3$ rainfall runoff

d.) $100{,}000\ m^3$ rainwater + $5000\ m^3$ sewage =

$105{,}000\ m^3$ of waste water

$- 10{,}000$

$95{,}000\ m^3$ of untreated water bypass the plant

e.) Stormwater runoff can be reduced by decreasing the amount of impervious surfaces in favor natural ground. Also planting more trees and vegetation will help to absorb water.

f. Extensive Paved areas can contribute to thermal pollution because paved surfaces trap heat.

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2C1

2. Like many communities, Fremont has a combined sewer system that collects both sewage and storm water. When storm water runs into storm drains that connect to the city's sanitary sewer system, the storm water and sewage flow together to the Fremont Wastewater Treatment Plant (FWTP). During a major storm event, however, the combined volume of storm water and sewage may exceed the plant's capacity, and the overflow bypasses the FWTP. The untreated overflow is discharged into Fremont Creek along with the treated waste.

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(e) **Describe** TWO ways that the volume of storm-water runoff can be reduced.

(f) **Describe** one environmental problem (other than pollution from runoff and from untreated sewage) that results from having extensive paved areas.

a) One pollutant in storm-water runoff that degrades the quality of surface water is nitrates from fertilizers. Another pollutant is fecal coliform ~~bacteria~~ from animal waste from farms.

b) $5\ \text{cm} \times \frac{1\ \text{m}}{100\ \text{cm}} = 0.05\ \text{m}$

$0.05\ \text{m} \times 200\ \text{m} \times 100\ \text{m} = 1{,}000\ \text{m}^3$

$20000 \times \frac{5}{100} = 1000$

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ADDITIONAL PAGE FOR ANSWERING QUESTION 2

c) $0.05\text{m} \times \frac{1\text{ km}}{1{,}000\text{ m}} = \frac{5}{100{,}000}\text{ km}$ $\quad 200 \times 100 = 20{,}000$

$\frac{5}{100} \times \frac{1}{1000} = \frac{5}{100{,}000}$

$\frac{5}{100{,}000}\text{ km} \times 10\text{ km}^2 = \frac{5}{100{,}000}\text{ km}^3 \times \frac{1000\text{ m}^3}{1\text{ km}^3} = 0.5\text{ m}^3$

$\frac{5q}{100{,}000}$ $\quad \frac{5{,}000}{100{,}000}$

$10\text{ km}^2 \times \frac{1000\text{ m}^2}{1\text{ km}^2} = 10{,}000\text{ m}^2$

$10{,}000 \times \frac{5}{100}$ $\quad 10{,}000\text{ m}^2 \times 0.05\text{m} = 500\text{ m}^3 \times \frac{20}{100} = 100$.

10×1000 $\quad 20{,}000\text{ m}^3$ $\quad 100000$

$10\text{ km}^2 \times \frac{1{,}000\text{ m}^2}{1}$

$0.05\text{m} \times$

$\frac{2\text{ km}^2}{1\text{ km}^2} = \frac{2}{1} \quad 2\text{ km}^2 \times 1{,}000 = 2000\text{ m}^2$

d) volume of ~~start~~ storm-water runoff — 5,000 m^3 of storm water

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ADDITIONAL PAGE FOR ANSWERING QUESTION 2

e. One way the volume of storm-water can be reduced is increasing the size of the wastewater treatment plant. While this is the more expensive route, increasing the surface area containing the water will decrease its volume. Another way to reduce the volume of storm-water runoff is capture the storm-water by planting plants and crops that can absorb the water before it runs off and collects pollutants.

f. One environmental problem of having extensive paved areas is that deforestation would be needed to clear areas for pavement. Deforestation would destroy animal habitats and eliminate plants that are beneficial in absorbing carbon dioxide.

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AP® ENVIRONMENTAL SCIENCE
2014 SCORING COMMENTARY

Question 2

Overview

This question was intended to determine students' knowledge of problems associated with storm-water runoff. They were asked to identify pollutants in runoff and to perform calculations relating to the volume of storm-water runoff and the amount of untreated storm water that would bypass a water treatment plant after a certain rain event. Students were asked to describe two strategies for reducing storm water runoff and to describe a non-pollution-related problem that would result from having extensive paved areas.

Sample: 2A
Score: 10

Two points were earned in part (a): 1 point for indicating that nitrates are a pollutant in storm-water runoff that degrades the quality of surface water and 1 point for indicating that phosphates are a pollutant in storm-water runoff that degrades the quality of surface water. Two points were earned in part (b): 1 point for indicating the correct setup (including units) and 1 point for indicating the correct answer. Two points were earned in part (c): 1 point for indicating the correct setup (including units) and 1 point for indicating the correct answer. One point was earned in part (d) for indicating the correct answer, with work shown. Two points were earned in part (e): 1 point for indicating that reducing the area that impervious surfaces cover would allow some water to percolate or infiltrate through the ground and 1 point for indicating the creation of large basins to collect gray water to use when flushing toilets. One point was earned in part (f) for indicating that extensive paved areas can lead to reduced infiltration, which can result in reduced replenishment of groundwater.

Sample: 2B
Score: 8

Two points were earned in part (a): 1 point for indicating that oils are a pollutant in storm-water runoff that degrades the quality of surface water and 1 point for indicating that litter is a pollutant in storm-water runoff that degrades the quality of surface water. Two points were earned in part (b): 1 point for indicating the correct setup (including units) and 1 point for indicating the correct answer. Two points were earned in part (c): 1 point for indicating the correct setup (including units) and 1 point for indicating the correct answer. One point was earned in part (d) for indicating the correct answer, with work shown. One point was earned in part (e) for indicating that planting more trees and vegetation will help to absorb water. No point was earned for identifying the strategy of decreasing the amount of impervious surfaces in favor of natural ground because no description is provided for how doing so would reduce runoff. No point was earned in part (f).

Sample: 2C
Score: 6

Two points were earned in part (a): 1 point for indicating that nitrates are a pollutant in storm-water runoff that degrades the quality of surface water and 1 point for indicating that fecal coliform is a pollutant in storm-water runoff that degrades the quality of surface water. Two points were earned in part (b): 1 point for indicating the correct setup (including units) and 1 point for indicating the correct answer. No points were earned in part (c). No point was earned in part (d). One point was earned in part (e) for indicating the strategy of capturing the storm-water by planting plants and crops that can absorb the water. One point was earned in part (f) for indicating that extensive paved areas would require deforestation to clear areas for pavement, which would destroy animal habitats and eliminate plants.